Pest Management Evaluation for for California Strawberry Nurseries

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Disclaimer

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Acknowledgements

Much of the information used in the preparation of this evaluation for strawberry nurseries came directly from the USDA OPMP & PIAP Crop Profile for Strawberries in California, December 20, 1999. This document contains the most current information on pest problems in strawberries in California (production and nurseries) and the management of those problems. Special recognition is given to Dr. Kirk Larson, Extension Pomologist, University of California South Coast Research and Extension Center, Irvine, California. Dr. Larson has conducted extensive methyl bromide alternatives research in strawberry nurseries and he is considered one of the most authoritative professionals in the state on the production of strawberry plants in California and the importance of pest management by soil fumigation for this industry.

Abstract

California is the world's leading producer of strawberry plants with approximately one billion plants produced each year on approximately 4,000 acres. Commercial strawberry plant propagation is a multi-year process. Runner plants produced in one nursery propagation cycle are used as planting stock in the next cycle. The first runner generation is produced in a screen-house, with at least three additional runner generations produced in field nurseries. Two or more field propagation cycles occur in low elevation (less than 500 ft. elevation) nurseries. A final propagation cycle occurs in high elevation nurseries (at greater than 3,200 ft. elevation). Nursery location and nursery production practices affect transplant performance in California strawberry fruit production systems. All pesticide recommendations for strawberry nurseries are presented in this evaluation with an emphasis on the use of methyl bromide/chloropicrin soil fumigation. This emphasis is given because all pesticide recommendations for strawberry nurseries are based on the use of methyl bromide/chloropicrin to help reduce reliance on other pesticides to manage pests in strawberry nurseries.

Pest Management Evaluation

Introduction: California nurseries supply almost 100% of strawberry root stock used within California and a significant portion of the stock used as the foundation for strawberries in other states and countries. California is the world's leading producer of strawberry plants. Approximately one billion plants are produced in California nurseries each year. California farmers use around 600 million plants annually and the rest of plants are (approximately 400 million plants are exported to other states, Canada, Europe and Asia. Methyl bromide in combination with chloropicrin is used to produce 100% of California nursery stock, including planting stock used in organic production. Because of the ozone depletion potential of methyl bromide, it will be phased out of production and use by the year 2005, with a 70% reduction in use by 2003.

California strawberry nurseries produce about 1,000,000,000 runner plants each year, with a farm gate value estimated at about $60,000,000. California is the world's leading producer of strawberry plants. As a result of climate, geography, modern nursery production and post-harvest handling systems, and the Strawberry Certification Program administered by the California Department of Food and Agriculture, California nurseries produce high quality strawberry plants that are marketed to nursery and fruit growers throughout the United States and worldwide. Approximately 15% of production is marketed outside California. For plants sold out-of-state, about 40% are sold for nursery planting stock, and the remainder are sold for fruit production purposes. (USDA OPMP & PIAP Crop Profile for Strawberries in California, December 20, 1999).

In California, commercial strawberry plant propagation is a multi-year process. Runner plants produced in one nursery propagation cycle are used as planting stock in the next cycle. The first runner generation is produced in a screen-house, with at least three additional runner generations produced in field nurseries. Two or more field propagation cycles occur in low-elevation (less than 500 ft elevation) nurseries in the state's interior valleys (primarily the Sacramento Valley) where climatic conditions result in prolific runner production during a long growing season. A final field propagation cycle occurs in high-elevation nurseries in northeastern California (at greater than 3,200 ft elevation), where temperature and photoperiodic conditions limit nursery runner production but result in increased transplant vigor, productivity, and fruit quality. Nursery location and nursery production practices effect transplant performance in California strawberry fruit production systems.

Nursery stock for summer-planted fields comes from low-elevation nurseries located in the Central Valley. These nursery fields are planted in the mid-Spring and harvested at the end of the calendar year. The resulting nursery stock are trimmed, packaged, and kept in cold storage until transplanting into fields the next summer. High-elevation nurseries are used for fall plantings. In these cases, harvested nursery stock are used immediately for transplanting into production fields.

Location of Low and High Elevation Nurseries: California high elevation nurseries are widely dispersed across soil types, climates and townships in California. However, Butte valley has the highest concentration of high elevation nurseries, and is also frequently the coldest

nursery area. About 75% of california low elevation nurseries are located in the San Joaquin Valley near the towns of Monteca and Turlock. Other areas important in the production of strawberry nursery stock in California are near the towns of Orland, Anderson, Marlin, McArthur, Fall River, Turle Lake, Bonanza and Susanville (Dr. Kirk Larson).

All nursery stock must be free of insects and plant pathogens to meet the strict certification requirement mandated by the California Department of Food and Agriculture.

Current Pest Management Practices: All pest management strategies for strawberries grown in California are based on the utilization of certified pest/disease free nursery stock growing in soil treated with methyl bromide/chloropicrin. All of the certified pest/disease free nursery stock was also grown in soil fumigated with methyl bromide/chloropicrin. For these reasons, the use of methyl bromide is currently essential as a pest management tool for this highly specialized industry. Finding and developing successful alternatives represents a significant challenge for the scientific community.

All soilborne pests of strawberries, including strawberry plants produced in nurseries are currently controlled directly by fumigation with methyl bromide/chloropicrin and several pests are managed more effectively from an indirect effect of fumigation with methyl bromide/chloropicrin. The following sections of the evaluation identify what is now being done to manage pests in strawberry nurseries as well as in production fields in California:

Insects

Insect pests controlled directly from fumigation with methyl bromide/chloropicrin follow. Efficient management of these pests in strawberry nurseries relies heavily upon finding and developing viable methyl bromide alternatives:

Root Weevils – Cribrate Weevil (*Otiorhynchus cribricollis*); Wood Weevil (*Nemoceates incomptus*); Black Vine Weevil (*Otiorhynchus sulcatus*); Fuller Rose Weevil (*Pantomorus cervinus*).

Damage. Root weevil larvae feed on the roots of strawberry plants and can completely devour small rootlets and destroy the bark and cortex of larger roots. Soon after feeding begins, plants wilt because the roots can no longer provide moisture for leaves. It is not uncommon to find weevil larvae that have penetrated into the lower portion of the plant's crown. These pests caused major economic damage in the 1950s prior to the onset of methyl bromide use. As a result, root weevils are anticipated to become an increasingly important pest in the next few years as methyl bromide is removed from the marketplace.

Description of Pest. Adult root weevils are beetles. They feed at night and hide around the crowns of plants during the day; they cannot fly. Adults feed on foliage and remove large scallops from the leaves. Such leaf damage is a good indication that weevils are present, but is not economically damaging to the plants. The adults, nearly all females, emerge in late spring or summer and feed on strawberry foliage. Eggs laid on the plants, after hatching, work their way

into the soil and feed on strawberry roots and crowns. In spring, they resume feeding and can cause extensive damage before they pupate. Root weevils have a single generation each year.

Monitoring. Observations for infestation such as crown damage. Though some damage is acceptable, severe damage triggers control methods.

Controls

Cultural:

- Crop Rotation. Annual plantings reduce the likelihood of high populations building up in fields. Crop rotation with non-host cover or cash crops may also help to reduce infestations.

- Sticky Barriers. Sticky barriers are used to prevent movement of adult weevils from infested second year berries and host areas to newly fumigated plantings. Adult weevils overwinter in nearby native plants, ornamentals, blackberries or in second-year strawberries.

- Weed-Host Control. Control of host plants adjacent to fields helps to reduce the potential for infestation.

Biological:
No known biological controls of root weevils.

Chemical:

- Soil Fumigation - General. Soil fumigation with methyl bromide and chloropicrin for weed and disease control has greatly reduced the presence and effect of root weevils. Prior to the use of methyl bromide, root weevils were a major economic pest of strawberries. Currently, root weevils require management only in a few central coast locations. However, with the impending loss of methyl bromide as a soil fumigant, it may be anticipated that root weevil management throughout the growing regions will increase. None of the currently registered chemicals will control these weevil larvae.

- Methyl Bromide/Chloropicrin. Methyl Bromide with chloropicrin is applied as a preplant application, approximately 30 days prior to planting, to fields at a rate of 300 to 400 lbs ai combination/acre. It is applied to essentially all of the conventionally grown strawberry fields in California for control of pathogenic fungi, weeds, and nematodes.

- Methyl bromide is a restricted use material that may only be applied by permit from the county agricultural commissioner. Many use restrictions apply. The restricted entry interval for methyl bromide is 48 hours.

For the following non-fumigant treatments, large application rates and ample water are needed to ensure penetration into the soil-based habitats of root weevils. The efficacy of these products is dependent upon using them in strawberry fields previously fumigated with methyl

bromide/chloropicrin.

- Diazinon. Diazinon is applied to strawberry fields at an average rate of about 0.8 lb ai/acre. Rates used to control root weevil are typically higher to maintain adequate dosage because high volume applications are necessary to penetrate soil. It is registered for use on strawberries to control root weevils but is not very effective compared to the fumigants. It may injure mite predators, resulting in an increase of twospotted spider mites. Diazinon is used to treat approximately 8% of strawberry acreage. The restricted-entry interval for diazinon is 24 hours.

- Bifenthrin. Bifenthrin (BRIGADE) is a relatively new chemical tool available to California strawberry growers and is applied at a rate of 0.05 to 0.2 lbs ai/acre to control root weevil. Synthetic pyrethroids such as bifenthrin are best when used at or near the end of the season due, in part, to their disruption of beneficial insects and predatory mites and the resulting infestations from other pests. This may not be the optimal treatment timing to achieve control. High application rates are needed to impact root weevil damage. For control, bifenthrin applications must be made early in the development of the weevil infestation. Although this material can impact root weevils, it is used primarily to control lygus. Use of bifenthrin is limited to 2 applications/year. The restricted-entry period for bifenthrin is 12 hours.

- Methomyl. Methomyl (LANNATE) is a carbamate that can be used to control root weevils when populations are anticipated to be high. Average methomyl applications are about 0.8 lb ai per acre with an average of 1 application per season. Application rates to control root weevils need to be higher than 0.8 lbs ai/acre. Methomyl was applied to about 25% of strawberry acreage in 1996, primarily for the control of lygus bugs and for caterpillar control. The restricted entry interval for methomyl is 2 days.

- Chlorpyrifos. Chlorpyrifos (LORSBAN) is a broad-spectrum insecticidal organophosphate applied at an average rate of about 1 lb ai/acre to approximately 15 % of strawberry acreage though applications of this insecticide can be targeted toward many pests, not just root weevil. Higher application rates are typically needed to control root weevils.

- Chlorpyrifos is critical for weevil control in southern California. The restricted-entry interval for chlorpyrifos is 24 hours.

- Carbofuran. Carbofuran (FURADAN) is a carbamate that can be used to control root weevils. Limited applications (less than 0.1% of strawberry acreage) of carbofuran were made. Application rates are about 2 lbs ai per acre. The restricted entry interval for carbofuran is 24 hours.

Hoplis Beetle, White Grubs - (*Hoplia oregona*)

Damage. Hoplia larvae, or white grubs, typically feed on perennial grasses but may attack strawberries feeding on the roots of strawberry plants. Small rootlets may be devoured and the bark and cortex of larger roots destroyed. Injured plants wilt as the roots can no longer provide moisture from leaves. Hoplia may be found throughout California but is most frequently found in the Central Valley. Damage is rarely seen in fumigated fields. Hoplia larvae has become a serious pest in nonfumigated fields in the Central Valley, where it has killed half the plants in heavily infested fields.

Description of Pest. Adults are brown beetles that are active for about two weeks after emerging in May, feeding on plants, mating and laying eggs on the soil. Adults are inconspicuous because they fly poorly. Hoplia larvae are white grubs that feed on plant roots for up to two years before pupating. Soil fumigation has kept white grubs from becoming a problem.

Monitoring. Growers monitor the fields for evidence of beetles or damage from larvae. Injured plants often develop in a small circular area. Though some damage is acceptable, sever damage triggers control methods.

Controls

Cultural:

- Crop Rotation. Annual plantings reduce the likelihood of high populations building in fields. Crop rotation with non-host cover or cash crops may also help reduce infestations.

- Weed-Host Control. Control of host plants adjacent to fields helps to reduce the potential for infestation.

Biological:
No known biological controls of hoplia larvae.

Chemical:

- Soil Fumigation - General. Soil fumigation with methyl bromide and chloropicrin for weed and disease control has greatly reduced the presence and effect of Hoplia beetle and white grubs. Currently, Hoplia beetles rarely require management due preplant fumigation. However, with the impending loss of methyl bromide as a soil fumigant, it may be anticipated that Hoplia beetle management throughout the growing regions will increase.

- Methyl Bromide with Chloropicrin. Methyl Bromide with chloropicrin is applied as a preplant application, approximately 30 days prior to planting, to fields at a rate of 300 to 400 lbs ai combination/acre. It is applied to essentially all of the conventionally grown

strawberry fields in California for control of pathogenic fungi, weeds, and nematodes.

- Methyl bromide is a restricted use material that may only be applied by permit from the county agricultural commissioner. Many use restrictions apply. The restricted entry interval for methyl bromide is 48 hours.

Garden Symphylan - (*Scutigerella immaculata*)

Damage. Garden symphylans damage plants by feeding on roots, thus retarding plant growth. They are usually only a problem in fields that were not fumigated, or if the fumigation was ineffective.

Description of Pest. Garden symphylans are slender and white. They occur mainly in moist soils with good structure and a high organic matter content, and are often associated with debris from a previous crop that is not completely decomposed. Since these pests rarely leave the vicinity of their infestation, they return to damage the same area every season so infestations spread slowly.

Controls

Cultural:

- Flooding. Continuous flooding for 3 weeks in the summer helps reduce infestations though this practice is not feasible.

- Crop Rotation. Growers sometimes grow and disc in a cover crop of sorghum to reduce infestations in other crops.

Biological:
There are no known biological controls that specifically target the garden symphylan.

Chemical:

- Soil fumigation, with methyl bromide and chloropicrin, for weed and disease control also controls garden symphylans. None of the registered insecticides will control this pest.

- Methyl Bromide and Chloropicrin. This combination of fumigants, when used preplant to control weeds, nematodes and other pests, also controls garden symphylans. Methyl bromide is being phased out so this sole chemical pest management tool will not be available and alternate controls are not available. Infestations by symphylans could become worse in future years as a result of this transition.

Indirect Benefits of Soil Fumigation

Insect pests managed more effectively as a result of fumigation with methyl bromide/chloropicrin, hence resulting in less use of chemical pesticides, include some secondary pests of strawberry nurseries [e.g. Black Cutworm (*Agrotis ipsilon*), Rangehemmed Cutworm (*Athetis minduror*), Beet Armyworm (*Spodopter exigua*)] as a result of weed control. Weed control is paramount in preventing a serious cutworm problem. Weedy fields tend to attract more moths to lay their eggs.

Diseases

Verticillium Wilt – (*Verticillium dahliae*)

Damage. Verticillium wilt is becoming an increasingly important disease in California strawberries. It is slow growing but, once established, it is extremely difficult to eradicate. Spread of the disease from contaminated planting stock is an increasing concern, making control of this disease at the nursery stage crucial. The pathogen is a soil-borne fungus and the loss of the methyl bromide/chloropicrin combination fumigant is anticipated to have a significant adverse effect by increasing the prevalence of Verticillium wilt. Verticillium wilt causes outer leaves to exhibit marginal and interveinal browning, followed by eventual collapse. Inner leaves remain green but are stunted and exhibit brownish black streaks or blotches. This last symptom distinguishes this disease from crown rot. Outbreaks of the disease typically result in observable "streaks" or "stripes" within the field.

Description of Disease. The fungus is not host specific and infects many weed species and crops worldwide. It is especially destructive in semi-arid areas where soils are irrigated. Inoculum densities may be high following planting of susceptible crops. Disease severity is greater when excessive levels of nitrogen are used.

Monitoring. The most common indication of Verticillium wilt is the observation of brown or dead outer leaves with green inner leaves.

Control

Cultural:

- Fertilizer Limitation. High nitrogen fertilizers are avoided since the disease severity is greater when levels of soil nitrogen are excessive.

- Crop Rotation. Growers with infested fields can rotate the fields to crops that are less susceptible to Verticillium wilt. However, Verticillium infects a wide variety of crops and relatively few rotational crop choices are viable. Also, Verticillium wilt (microsclerotia) may remain viable in soil for up to 20 years suggesting that a rotation cycle of 20 years or more is

necessary.

- Irrigation Control. Use of drip irrigation and other irrigation practices that limit spread of this soil-borne disease can be helpful.

- Fertilizer Limitation. High nitrogen fertilizers are avoided since the disease severity is greater when high levels of soil nitrogen are present.

- Field Selection. Selection of fields that are free of the disease is an important factor. In particular, organic growers try to select fields isolated from conventional growing areas, when possible.

- Resistant Cultivars. Growers can use less susceptible cultivars when practical, though resistance to Verticillium wilt is rarely an important criteria selection of current commercial varieties. However, all current California varieties are susceptible to Verticillium wilt in comparison to other crop hosts.

Chemical:

- Chloropicrin . Though currently applied in combination with methyl bromide, chloropicrin is the more effective of the two fumigants against Verticillium wilt. When used alone chloropicrin at rates of less than 200 lb ai per acre are not sufficiently effective. If Verticillium wilt is an important concern in the treated field, the proportion of chloropicrin to methyl bromide is increased. Chloropicrin is more effective for Verticillium wilt when used in combination with methyl bromide than when used alone. Chloropicrin is currently applied to almost all the strawberry acreage in California in combination with methyl bromide. San Diego County does not permit the use of chloropicrin alone. There are numerous restrictions on the application of this restricted-use pesticide.

- Methyl Bromide/Chloropicrin. Methyl Bromide with Chloropicrin is applied as a preplant application to fields at a combined rate of 300 to 400 lbs/acre. It is currently applied to essentially all of the commercial acreage, both production and nursery, in California. Since chloropicrin is the more effective of these two chemicals against Verticillium wilt, the relative proportion of chloropicrin is increased in fields where the control of this disease is important. The restricted-entry interval for methyl bromide/chloropicrin is 48 hours.

- Metam Sodium. Metam sodium is applied at a preplant soil drench to less than 1% of treated fields. Metam-sodium can be a marginally effective preplant material provided it gets to the target organism. Metam sodium delays growth of Verticillium but does not get down deep enough in the soil to effectively control the disease. The restricted-entry interval for metam sodium is 48 hours.

Phytophthora Crown Rot & Root Rot - (*P. cactorum*; *P. citricola*; *P. parasitica*; *P. megasperma*)

Damage. Phytophthora is a genus of soil-borne fungi. Stunting is common. Initially, the youngest leaves on the strawberry plant begin to wilt and also may turn bluish green in color. Plant collapse also occurs rapidly or slowly, depending on the Phytophthora species involved. When infected plants are cut open, a brown discoloration can be seen throughout the crown tissue. Phytophthora species also attack root tissue, causing a brown to black root rot.

Description of Infection. Motile spores (zoospores) are released into the soil and swim to plant tissue when the soil becomes saturated with water for prolonged time periods. When the soil drains and dries, zoospores either encyst or die. Mycelium in infected tissues make resistant structures that overwinter and survive harsh conditions.

Control

Cultural:

- Low Moisture. Cultural control of the fungus includes locating strawberry fields on well drained soil, using raised beds to provide optimum drainage, and using less susceptible cultivars. Use of drip irrigation and managing irrigation schedules to minimize soil saturation near plant crowns are key methods reducing losses from this pathogen. Planting in low lying areas that regularly receive excess water and are poorly drained is avoided.

- Resistance/Prevention. In so far as possible, growers also use clean plant stock when available and cultivars suitable for local conditions that have disease tolerance.

- Varieties . Though some varieties are less susceptible to Phytophthora, this is rarely an important basis for varietal selection by the growers. Furthermore, resistance in main varieties is incomplete to phytophthora.

Chemical:

- Methyl Bromide/Chloropicrin. Fumigating the soil with methyl bromide/chloropicrin is a key component of crown rot control, although the use of fungicide soil drenches or sprays is also of use. Methyl Bromide with chloropicrin is applied as a preplant application to fields at a combined rate of 300 to 400 lbs/acre to control Phytophthora crown rot. It is typically applied to essentially all of the fruit production acreage and to all nursery acreage in California. Methyl bromide applications are highly controlled and restricted and the active ingredient will no longer be available in 2006. The restricted-entry interval for methyl bromide/chloropicrin is 48 hours.

Common Leaf Spot – (*Ramularia tulasneii*)

Damage. Common leaf spot is the most important of the strawberry leaf spot diseases in California. The disease is not as important as it has been in previous years, particularly in south coast regions. However, the disease can decimate the productivity of fields if unchecked. The

pathogen is introduced into fruit production fields as small, black sclerotia on infected nursery material. Germination of sclerotia is initiated by fall and winter rains or sprinkler irrigation. Spores are dispersed by wind-driven rain. Common leaf spot can be a problem in all nursery and fruit production areas, but is usually less prevalent in the drier interior valleys and southern growing regions.

Description of Infection. Small, deep purple spots initially appear on the upper surface of leaves, with the center portion of the lesion turning brown then grey to white depending on the age of the leaf and environmental conditions. Numerous spots may coalesce to kill the leaf. On petioles, stolons, calyxes, and fruit trusses, elongated sunken lesions may form and interfere with water transport in the plant, weaken the structure, or allow invasion by secondary organisms.

Controls

Cultural:

- Drip Irrigation. Overhead irrigation is avoided. The use of drip irrigation can limit the onset of the disease.

- Leaf Removal. Though not always practical, removal of infected leaves can limit spread of the disease.

- Clean Stock. Attempts are made to insure that planting stock is clean, limiting introduction of the disease into a new field.

Chemical:

Protective fungicides are effective if used at the appropriate time. Applications are made in anticipation of warm, damp weather.

- Methyl Bromide/Chloropicrin. Methyl Bromide with Chloropicrin is applied as a preplant application to fields at a rate of 300 to 400 lbs/acre to kill overwintering sclerotia. It is typically applied to essentially all fruit production acreage and all nursery acreage in the state. Methyl bromide/chloropicrin is effective against sclerotia in the soil. These applications are highly restricted and methyl bromide is being phased out by 2005. The restricted-entry interval for methyl bromide/chloropicrin is 48 hours.

- Chlorothalonil. Chlorothalonil (BRAVO) is an aromatic hydrocarbon derivative applied at rates of about 1 lb ai/acre to nonbearing stock in nurseries only. It is applied to about 3% of overall strawberry acreage (which is a significant portion of the state's nursery acreage). This material is available as a special local needs registration and may only be applied by permit from a county agricultural commissioner. Chlorothalonil should not be used with or closely following spray oils. There is no restricted reentry period.

- Captan. Captan is a N-trihalomethylthio applied at 2 lb ai/acre to over 90% of treated acres of strawberry fields with an average of 3 applications per year (though these applications are typically targeted towards the control of other diseases. It is not applied in combination with or immediately following application of spray oils. The restricted entry interval is 1 day.

- Benomyl. Benomyl (BENLATE) is a carbamate applied at rates of 0.5 lb ai/acre onto about 40% of the strawberry acreage though typically not targeted toward common leaf spot. Rarely used alone, benomyl is typically used in combination with captan or other fungicides. A total of 5 lbs ai per acre per year is the maximum rate allowed. The restricted reentry period is 4 hours.

- Copper Hydroxide. Copper hydroxide provides some control of common leaf spot at label rates. It is applied to about 9% of strawberry acreage. The restricted reentry interval is 48 hours.

- Myclobutanil. Myclobutanil (RALLY) is an azole fungicide applied at a rate of 0.1 lb ai/acre. It is applied to approximately 65% of strawberry acres though primarily targeted towards the control of other diseases. The average number of applications per year is 2 though up to 6 applications per year are allowed. Though effective against common leaf spot, it must be applied in conjunction with its targeted use against powdery mildew. The restricted entry interval for myclobutanil is 48 hours.

- Potassium Bicarbonate. Potassium bicarbonate (KALIGREEN) is a new product available to the industry. Though less effective than traditional chemical treatments against common leaf spot, this product works well in rotation with these products and is a good reduced-risk addition to an IPM program. The product is applied at a rate of 2.4 lb ai per acre. It should be applied in cooler climates as applications during higher temperatures may cause bronzing of fruit. There is no data yet on the extent to which this new active ingredient is being used on strawberries in California. The restricted reentry period is 4 hours.

Anthacnose – (*Colletotrichum ocutatum*)

Damage. Anthracnose is a sporadic disease that is most common in wet, El Nino years , especially in Southern California. Flowers, ripe and unripe fruit can be affected. Warm or cool, wet conditions favor the development of fruit and stem rot. Anthracnose can also cause root rot and crown rot. The worst problems from this disease come from nursery stock.

Description of Disease. On fruit, light tan to light brown water-soaked lesions develop and turn into sunken black lesions. Dark elongated fusiform lesions appear on petioles and runners, and often girdle the stem. Fungus overwinters in plant debris or alternate weed hosts.

Control

Cultural:

- Planting Stock. Anthracnose is most common on varieties that fruit in the nursery. Contamination may occur in fruit production fields as a result of nursery infections or contamination of planting material. Growers use certified "clean" pathogen-free planting stock in fruit production fields and use drip irrigation to prevent the spread of disease, avoiding overhead sprinkler irrigation.

- Removal of Soil. Water (hot water, if possible) can be used to remove soil from planting stock prior to transfer and to reduce potential for transfer of disease.

Biological:

There are no specific biological control methods for anthracnose.

Chemical:

- Methyl Bromide/Chloropicrin. Methyl Bromide with Chloropicrin is applied as a pre-plant fumigation to fields at a combined rate of 300 to 400 lbs/acre. It is typically applied to essentially all of California's production and nursery acreage. Methyl bromide use is highly restricted and will be phased out by 2006, with a 70% reduction by 2003. The restricted-entry interval for methyl bromide/chloropicrin is 48 hours.

Post-Plant:

Day neutral varieties are treated in nurseries when plants begin to fruit. Treatments are made in the field before an expected rain.

- Myclobutanil. Myclobutanil (RALLY) is an azole fungicide applied at an average rate of 0.1 lb ai/acre. It is applied to approximately 65% of strawberry acres though primarily targeted towards the control of diseases other than anthracnose. Myclobutanil can be effective against anthracnose but must be used in conjunction with treatments targeting powdery mildew. The restricted entry interval for myclobutanil is 48 hours.

- Benomyl and Captan. A combination of benomyl and captan is the typical treatment for anthracnose. It is not applied in combination with or immediately following application of spray oils. The restricted entry interval is 1 day.

- Captan. Captan is a N-trihalomethylthio fungicide applied at an average rate of 2 lb ai per acre. It is not applied in combination with or immediately following application of spray oils. The restricted entry interval is 1 day for captan.

The following active ingredients are not currently registered for strawberries but are needed tools as soon as possible. An expedited registration is encouraged by the

industry.

- Azoxystrobin . Azoxystrobin (QUADRIS) is a new active ingredient that is needed for strawberries in California for disease control and to manage fungicide resistance.

- Cyprodinil With Fludioxonil. The combination of cyprodinil and fludioxonil (SWITCH) is available as a Section 18 for Strawberries in southeastern United States. This reduced risk combination is needed now for disease control and to manage fungicide resistance.

Angular Leaf Spot – (*Xanthomonas fragariae*)

Damage. The adverse impacts of angular leaf spot are increasing. The disease is a severe problem in all nursery locations and is becoming more of a problem in fruit production regions such as the central and south coast. The disease is favored by cool, moist days with cold nights near freezing. Infection first appears as minute, water-soaked spots on the lower surface of leaves. The lesions enlarge to form translucent, angular spots that are delineated by small veins and often exude a viscous ooze, which appears as a whitish and scaly film after drying. As the disease progresses, lesions coalesce and reddish brown spots, which later become necrotic, appear on the upper surface of the leaves. A chlorotic halo usually surrounds the infected area.

Description of Disease. This bacterium is not free living in soil. It can, however, overwinter in soil on previously infected plant material. Transmission is by splashing water. It is host specific and highly resistant to degradation. The disease can persist in the soil for long periods of time. It is killed by methyl bromide/chloropicrin mixture used as a preplant fumigant, so it is very likely that most initial infections in fields that have been fumigated originate from contaminated plants. Lesions on the leaf surface serve as a source for secondary inoculum and cells are dispersed by splashing rain or overhead irrigation. Although uncommon in California, Xanthomonas fragariae can cause vascular collapse and can be confused with phytophthora crown rot and root rot, Colletotrichum crown rot and Verticillium wilt. This symptom initially appears as a water-soaked area at the base of newly emerged leaves. Shortly after, the whole plant suddenly dies, much like plants infected with crown rot.

Controls

Cultural:

- Sanitation. Growers use certified clean planting stock though the certification system has become less reliable in recent years.

- Drip Irrigation. Growers avoid overhead irrigation whenever possible. Drip irrigation and other limited water programs can be effective in reducing spread of the disease.

Biological:
There are no specific biological control methods for angular leaf spot.

Chemical:
Chemical controls are typically ineffective against this pathogen.

- Methyl Bromide/Chloropicrin. Methyl Bromide with Chloropicrin is applied as a preplant fumigation to fields at a combined rate of 300 to 400 lbs/acre. It is typically applied to essentially all of California's production and nursery acreage. Methyl bromide use is highly restricted and will be phased out by 2006, with a 70% reduction by 2004. The restricted-entry interval for methyl bromide/chloropicrin is 48 hours.

- Fixed Copper. Fixed Copper is applied at label rates to approximately 10% of strawberry acreage. Copper can be phytotoxic to plants with repeat applications. The restricted-entry interval for fixed copper is 24 hours.

Nematodes

It is important to note that all discussion related to nematode control are based on pest management strategies utilizing certified pest/disease free nursery stock growing in soil treated with methyl bromide/chloropicrin.

Foliar Nematode
Aphelenchoides fragariae

Northern Root Knot Nematode
Meloidogyne hapla

Symptoms and Damage. The presence of either foliar or northern root knot nematodes may result in plant stress and reductions in yield. Under current practices of fumigating strawberry fields with methyl bromide and chloropicrin and using certified nursery stock, these nematodes are rarely found to cause significant damage in California production areas. However, with the impending loss of methyl bromide and the increasing use of organic methods damage will likely become more common. Control of these two pests by nursery stock producers is critical because an infestation will prevent the grower from receiving government certification, thereby reducing the value of the planting stock.

Plant symptoms can be indicative of a nematode problem but are not fully diagnostic because similar symptoms could result from other problems as well. The symptoms may either be widespread or may appear in small patches within a field. Aboveground symptoms of foliar

nematode include stunted growth, reddened leaves, small curled or crinkled leaves (crimp), deformed buds and flowers, and a reduction in flowering and fruiting. A reduction in flowering and fruiting may more reliably distinguish a foliar nematode infestation from insect infestations, which produce leaf symptoms similar to those described above. There are no reported below-ground symptoms with foliar nematodes. Aboveground symptoms of root knot nematodes include wilting during hot days, stunting, chlorosis, and suppression of fruit yields. Root galls formed near the root tips and abundant branching at and above the galls are the primary below ground symptoms of this pest.

Description of Pest. Plant parasitic nematodes are microscopic, unsegmented roundworms. The two species most commonly associated with damage in California strawberries are the foliar. nematode, Aphelenchoides fragariae , and the northern root knot nematode, Meloidogyne hapla Strawberries are also hosts for the following nematodes: root lesion (Pratylenchus penetrans), stem (*Ditylenchus dipsaci*), dagger (Xiphinema americanum) , needle (*Longidorus elongatus*), foliar (*Aphelenchoides ritzemabosi*, *Aphelenchoides besseyi*), and root knot (Meloidogyne *incognita* and *Meloidogyne javanica*). All of these nematodes are potential pathogens to strawberries in California and their identification in strawberry plantings or in land to be planted to strawberries are cause for concern.

Monitoring. To make management decisions, a grower must monitor the field by taking soil and plant samples, sending them to a diagnostic laboratory for identification. Sampling and extraction techniques are typically 30 to 50% effective in detecting species that might be present.

Controls

Cultural:

- Limitations on Transfer of Pest. The selection of planting site, non-infested planting stock, cleaning of equipment to minimize nematode transfer, avoidance of nematode-infested irrigation water, hot water treatments of planting stock, and crop rotations are cultural techniques used by growers to control nematode infestations.

- Solarization. There has been some experimentation where solar energy and has been used to help suppress nematode populations. It is not yet clear whether this technique can be a feasible alternative within an IPM program.

Biological:

There are no known biological control agents that have been shown to control or suppress nematodes.

Chemical:

- Methyl Bromide. Methyl Bromide is applied as a preplant application to fields at a combined rate, with chloropicrin, of 300 to 400 lbs/acre. It is typically applied in combination to essentially all of the state's acreage to provide control of pathogenic fungi, weeds, and nematodes. When used properly, methyl bromide provides excellent preplant control of root-infesting plant parasitic nematodes. Methyl bromide is a restricted use material that may only be applied by permit from the county agricultural commissioner. Methyl bromide is being phased out with interim reductions and will not be available for use starting 2006. The restricted-entry interval for methyl bromide is 48 hours.

- Metam Sodium. Metam sodium is applied as a preplant fumigant to less than 1% of strawberry fields. Metam-sodium is a preplant material for nematode control provided it gets to the target organism. If used properly, it can provide some nematode control in many situations, but it has a reputation of being consistent but relatively ineffective with regard to this control. These problems are due largely to nonuniformity of application as a result of land preparation and insufficient water for movement resulting in subsequent failure of the material to contact and kill the nematodes present. The restricted-entry interval for metam sodium is 48 hours.

- Oxamyl. Oxamyl is only registered for use on root knot, sting, burrowing, and root lesion nematodes on nonbearing nursery stock that will not bear fruit within 12 months after application. Some cultivars have exhibited phytotoxic symptoms; therefore, oxamyl is typically used on a small scale to determine crop sensitivity prior to large scale field application.

- Chloropicrin. Chloropicrin is typically applied in combination with methyl bromide for the control of pathogenic fungi, weeds, and nematodes. Efficacy data for chloropicrin alone is poor for nematode control on strawberries and is typically not used alone.

Weeds

Overview. The longer growing season of California strawberries results in a greater challenge to weed control. Effective weed management in strawberries requires a combination of cultural practices, preplant soil fumigation, and additional herbicide applications when necessary. Proper preplant field preparation is essential for a good weed control program. For weed and pathogen control, fumigation with a combination of methyl bromide and chloropicrin, or to a lesser extent metam sodium, in conjunction with plastic mulches, is a major method of weed control in California strawberry nurseries. For weeds that escape preplant controls, hand-weeding and/or selective herbicides are used. In some cases, organic mulches have been used instead of plastic ones.

Growers select sites with good drainage in areas with good quality water. Nursery sites are surveyed for perennial weeds. The broad-spectrum control of methyl bromide allows for the use of land that may have a weedy history, but less weedy sites are preferred. Certain weeds (such as hairy nightshade) host soil-borne diseases (such as Verticillium wilt). Treatment of these weeds, therefore, can result in a lower incidence of soil-borne diseases. Weeding crews are sent

through fields, as needed, to remove weeds.

The loss of methyl bromide in 2005, with incremental reductions of 25% in 1999, 50% in 2001, and 70% in 2003, will have a dramatic impact on the effectiveness of weed control in California's strawberry nurseries. Productivity losses in nursery plants are anticipated due to increasing competition for soil and sun and increased abundance of hosts for insect pests and diseases. Alternative fumigants, such as 1,3-D plus chloropicrin mixture and chloropicrin alone, are less active on weeds than methyl bromide. Therefore, weeding costs are likely to increase during and after the methyl bromide phase out.

Controls

It is important to note that all discussion related to weed control are based on pest management strategies utilizing certified pest/disease free nursery stock growing in soil treated with methyl bromide/chloropicrin in fruiting fields but there are no acceptable cultural methods for strawberry nurseries other than possibly hand weeding.

Cultural:
Weeds can be controlled culturally through the use of mechanical methods or with organic and synthetic mulches.

- Hand Weeding . During the early stages of plant establishment, mechanical removal, mostly by hand, is the most practical means for control. Timely removal of weeds is essential to minimize competition.

Chemical:
For effective weed seed control it is essential, regardless of fumigant, that the soil be pre-irrigated so that weed seeds are saturated with water before fumigation and that soil temperatures be above 55°F. The following fumigants are used for weed control.

- Methyl Bromide/Chloropicrin. Methyl Bromide with Chloropicrin is applied as a preplant fumigation to fields at a rate of 300 to 400 lbs/acre to control weeds and other soil-borne pests. This combination is currently applied to essentially all of the production and nursery acreage in the state. Soil fumigation must be performed at least 14 days before planting. This time period may vary with soil temperatures and dosage rates. Methyl bromide is being phased out and will no longer be available in 2006, with a 70% reduction by 2003. Weed control will be much more difficult without this effective, extremely broad-spectrum herbicide. Herbicide substitutes are not available to substitute for the spectrum of methyl bromide efficacy. The restricted-entry interval for methyl bromide/chloropicrin is 48 hours.

- Metam Sodium. Metam-sodium is an effective material provided it comes in contact with the target organism. Metam-sodium, a liquid at atmospheric conditions, is applied by several methods: it can be injected into sprinkler systems, shanked into soil and tarped. It is not a

direct substitute for methyl bromide and different application techniques are needed to obtain optimum results. Problems with applications are due largely to nonuniformity of application as a result of poor land preparation and insufficient soil moisture, resulting in subsequent lack of control against the targeted pests. Metam sodium is a restricted use material and may only be applied by permit from a county agricultural commissioner. Soil fumigation must be performed at least 14 days before planting. This time period may vary with soil temperatures, dosage rates, tarping and color, and soil type. The restricted-entry interval for metam sodium is 48 hours.